COLOUR OF THE SEA.

APROPOS of the report (NATURE, March 10) of Lord Rayleigh's lecture dealing with the parts played by reflection and transmission of light in the production of the integral impression of colour on the eye of an observer looking at the sea from the deck of a ship, I should like to be permitted to make some observations on the proper colour of the water of the ocean, as it is a subject which has occupied my attention, off and on, during the last forty years.

During the voyage of the *Challenger* I began to log the colour of the water in February, 1874, when she was working in the neighbourhood of the Antarctic circle. My attention was there directed to it by the frequent and abrupt passage of the ship from water of the clear indigo colour of the ocean of temperate latitudes to the deep olive-green water which is a distinctive feature of these icy regions.

The colour is due to the abundance of diatoms. These are so plentiful and so preponderant that, besides putting their stamp on the surface, they furnish a distinct type of oceanic deposit, the *diatom-ooze*. The green colour of the water is due, not only to the living diatoms, but also, and perhaps to a greater extent, to the excretions of the animals for the subsistence of which the diatoms furnish the ultimate food supply. The crowds of penguins and other birds to be met with in these seas stain all the ice green where they have rested. The water, inhabited by diatoms and affected by diatomaceous débris, has a deep olive-green colour which is characteristic, and this I accepted as one colour-type of the water of the ocean. It is seen best in the water the transparency of which is not interfered with by too great a crowd of the diatoms themselves. Water belonging to this type of colour is not confined to polar latitudes; it is met with in a certain class of homologous districts of the warmer ocean, in tropical and even in equatorial latitudes.

When we quit the edge of the polar ice and steer equatorwards, the surface water assumes a pronounced indigo colour, and this persists until we pass the fortieth parallel. If we start from the equator and sail polewards, the colour of the surface water persists as a pure and brilliant ultramarine until the thirtieth parallel is passed. The passage from the ultramarine to the indigo, and *vice versa*, is usually very rapid, and the area of mixture is restricted. No one who has once sailed in the ultramarine waters of the intratropical ocean and has observed, as well as seen, its colour, can ever mistake any other colour for it. If he has doubt as to whether the water through which he is passing is ultramarine or not, he may be sure that it is not. The ultramarine and the indigo are the two great colour-types to which the mass of the surface water of the deep sea belongs, and, with the olive-green, they make the three fundamental colour-types which are required, and are sufficient for the adequate logging of the colour of the surface water of the ocean.

The water of the Mediterranean belongs to the ultramarine type, but it always appears to me to have a harder tone than the soft and brilliant ultramarine of the intratropical ocean.

With regard to the method of judging the colour of the water, much unnecessary difficulty is made. The first precaution to be observed is to take up a position where the greatest amount of light can reach the eye after passing through the water, and the smallest amount after being reflected from its surface. There is generally little difficulty in accomplishing this on one side or the other of the ship and by looking as nearly as possible vertically into the water.

The *Challenger*, like other men-of-war of her date, was fully rigged, and built for sailing as well as for steaming. When under sail the propeller causes a certain amount of retardation, and to remedy this she was fitted with a "screw-well" into which the propeller could be hoisted out of the water. This proved to be a perfect observation tube for determining the proper colour of the water. Its diameter was about 6 feet; it passed from the upper deck through the captain's cabin on the main deck and the ward-room on the lower deck into the water. Looked into from the deck, the sea water appeared to be enclosed in it as the water is in a well, but with this difference, that the water, by day, was brilliantly illuminated from below. There being no clearance between the surface of the water in the well and the structure of the ship, no light could enter except through the water. No direct sky-light could reach it down the well, because the poop awning, which was practically always spread during the day, completely excluded it. The screw-well was, in effect, an artificial and perfected *Grotto di Capri*, which was carried round the world. It was perfected, inasmuch as there is a passage for boats to penetrate into the grotto from the outside, while the screw-well is entirely shut off. During the whole of the voyage the colour of the water was under observation in this very perfect apparatus.

The statement that the blue colour of the sea is nothing but the reflection of the blue of the sky was at first frequently made, even on days when the sky was completely overcast; a visit to the screw-well, especially on overcast days, never failed to convince the doubter that the water contained in its own mass sufficient colour to account for all that was perceived. When the ship was in green water the view was never advanced that its colour was due to reflection from the sky.

As ships with screw-wells long ago disappeared from the sea, it may not be superfluous to point out that what could be observed in the screw-well was altogether different from what can be seen in the wake of the screw of a modern steamer. While the screw-well was a perfect instrument for gauging the colour of the water, the determination of its transparency was more conveniently made from a boat. Thus in mid-Pacific, with the aid of a "water-glass" to eliminate the disturbing action of ripples, a metal plate measuring only 4 by 4 inches, painted white and not masked by the suspending line, was distinctly seen at a depth of 25 fathoms (45 metres). Beyond this depth it became indistinct, and became invisible at about 27 fathoms, but this was due mainly to its smallness and to its want of steadiness, being attached to the boat, which rose and fell with the swell. At 25 fathoms the plate had a pale ultramarine colour, and its edges were sharply defined. These separated the column of water, into which I looked through the water-glass, into a central column of rectangular section having a depth of 25 fathoms, and into a column, surrounding and contiguous with it, which had a depth many times greater. These columns, being juxtaposed, were placed in the way most favourable for the comparison of their colours. The colour of the central column, 25 fathoms in length, was a pure but pale ultramarine; that of the external and uninterrupted column through which the whole unabsorbed and undissipated part of the sunlight which had penetrated into the water returned to the surface was of the same tone, but of many times greater intensity. Assuming the intensity of the colour to be proportional to the length of the column of water traversed by the light, it is to be concluded that the length of the uninterrupted column which transmitted the more intense colour was many times greater than 25 fathoms. It must be noted that the glass plate forming the bottom of the small tub, which is called a "water-glass," was during the observation completely protected from direct sky-light by my head and the brim of the panama hat which, at that time, I always wore when exposed to the sun.

It has already been said that water of as pure a green as that of the Antarctic occurs in other and warmer districts of the ocean. My attention was first directed to this during the cruise of the *Dacia*, which, although it occupied no more than three weeks, marks an epoch in deep-sea research. A short account of it is given in a paper by me—"On Oceanic Shoals discovered in SS. *Dacia* in October, 1883"—and published in the Proceedings of the Royal Society of Edinburgh, 1885, xiii., p. 748. Perhaps the most remarkable of these shoals was the one which was named the "Coral Patch," in lat. 34° 57′ N., long. 11° 57′ W., the exploration of which, along with that of the tidal currents in the open ocean (Proc. Roy. Soc., 1888, xliii., p. 356), supplied the evidence which definitively established the fact that coral islands are a product of elevation and not of subsidence.

When the survey of this shoal had been completed, in so far as the time at the disposal of a steamer engaged on a commercial mission permitted, a line of soundings was run from the "Patch" to the African coast at Mogador. Independently of the high land which is visible from the sea at a distance of many miles, the approach to the coast is indicated by a fall in the temperature of the water of the sea surface, and a remarkable change in its colour. Outside, the temperature of the surface water was 21° C., and its colour was ultramarine. After sighting the land its temperature fell, at first slowly, then rapidly, and, when at a distance of two miles from Mogador, it was only 16° C. The colour at the same time had become a pure olive-green, which maintained its transparency until close to the shore, where it became masked by the solid matter kept continually in suspension by the mechanical energy of the breaking waves.

The pure green colour of the water and its temperature, so much lower than that which could persist at the surface of the sea in the latitude of Mogador, made me for a moment think that it might be in reality Antarctic water which had found its way, at or near the bottom, into the northern hemisphere, having been diverted first to the west while in the South Atlantic, then to the east after crossing the line. But this idea could persist only for a moment, because the temperature and the density of the bottom water were found to be those characteristic of the bottom water of the eastern basin of the North Atlantic, as shown by the *Challenger* observations, and these are much higher than those of any other ocean.

The low temperature of the water showed that it could not come on the surface from the north or south or west of it, and the only source from which it could come was from below the surface. Deep water comes close to the coast, and the water at 2000 fathoms was found to have a temperature of 2·5° C., so that the supply of cold from this source was adequate, and it was available with a very small expenditure of energy. Arrived at the surface and following the south-westerly drift of the surface water, exposure to the sun raised the temperature of the water and discharged its colour *pari passu*. It was evident that there was here a case of the rising of deep water at the weather coast of an ocean, away from which the prevailing wind was continually driving the surface water.

From Mogador the *Dacia* proceeded to the "Seine Bank," in lat. 33° 47′ N., long. 14° 1′ W., and explored it thoroughly. Among the specimens brought up on the grapnel were masses of dead coral and shells, all having the same green colour. Some of these fragments were preserved in spirit, which quickly assumed the green colour, leaving the shells and coral practically decolourised. I sent the bottle, with the specimens and spirit, to my friend Prof. W. N. Hartley, in Dublin, who was good enough to subject them to spectroscopic examination. He wrote to me on February 15, 1884:—"I have made a spectroscopic examination of the colouring matter you sent me and have no doubt that it is altered chlorophyll. I have got identical wave-length measurements for the absorption band with your liquid and a specimen of very pure chlorophyll dissolved in ether"; and he adds, "there is very little real substance in even a dark green solution."

As the year 1884 belongs now to the remote past, I recalled the matter to Prof. Hartley, and, confirming his previous information, he added:—"I believe my impression at the time was that the chlorophyll was the colouring matter in a living micro-organism, and that these settled upon the shells, but when not deposited they were floating in the sea water." I am obliged to Prof. Hartley for kindly permitting me to use these private communications. Further information will be found in his paper on chlorophyll from the deep sea (Proc. Roy. Soc. Edin., 1885, xiii., 130).

Prof. Hartley's report furnished a remarkable confirmation of my first impression in so far as it showed that the green water of the Mogador coast owed its colour to the same substance as did the diatom-crowded water of the Antarctic, namely, chlorophyll.

In April and May of 1885 I made a coasting voyage from Valparaiso to San Francisco. Excepting the equatorial part, stretching from Cape Blanco to Panama and round the coast of Central America to near Mazatlan, the west coast of the American continent between the fortieth parallels is the weather shore of the Pacific Ocean. All along it cold and green water is met with, in the same way as we have seen to be the case on the Atlantic coast of Morocco. On the South American coast the green water was found to extend, with few interruptions, from Valparaiso, lat. 33° S., to Cape Blanco, lat. 4° 27′ S. As on the Morocco coast, the green colour and the low temperature of the water are found only close to the shore. At a distance of ten miles outside the colour is blue, and the temperature normal for the latitude. There can be little doubt that, as the localities where the green water occurs are geographically homologous, so the substance which produces the colour is generically the same, namely, chlorophyll.

The following particulars are taken from my unpublished journal. The only ports or anchorages where the water was blue were Huasco, lat. 28° 27′ S., temperature of the surface water 14·7° C., and Carizal, lat. 28° 5′ S., temperature 15·1° C. The occurrence in this latitude of blue water with so low a temperature is very remarkable.

At Antafogasta, lat. 23° 39′ S., the water was greenish-blue, and its temperature was 18·0° C. Between this port and Iquique the ship's course took her to a distance of nearly twenty miles from the coast, and there the colour of the water was ultramarine and its temperature 21·2° C. At Iquique the water was quite green, and its temperature 17° C. Between this port and Arica the water was quite green, even at a distance of five miles from the coast, where the temperature was 19·5° C., but on anchoring at Pisagua, lat. 19° 36′ S., the temperature of the water was only 15·2° C. At Arica, lat. 18° 28′ S., the water was equally green, but its temperature was 19·5° C. Arica lies in the angle where the trend of the coast changes from north to about north-west. From Arica the ship made a longer run to Chala, lat. 15° 49′ S., keeping at a distance of fifteen to twenty miles from the coast. Here ultramarine water was met with, its temperature rising to 23·2° C., but even at fifteen miles from this coast some green water was met with having a temperature of 18·8° C. I attributed this to the foggy state of the atmosphere which prevailed. This obscured the sun, and retarded both the heating and the bleaching of the water. In lat. 14° 8′ S., when six miles off shore, the water was quite green, and its temperature 15·1° C. Outside of Callao, lat. 12° 0′ S., the water was green, and its temperature 16·3° C.; in the harbour its temperature was 17·5° C., and its colour a dirty green, turbid and milky with sulphur, smelling strongly of sulphuretted hydrogen, and full of dead fish. Continuing northwards, off Ferrol Islands, lat. 9° 11′ S., the temperature of the water was 16·0° C., and its colour olive-green. At Payta, lat. 5° 5′ S., the temperature of the water was 17·1° C., and its colour a chalky green.

The green and cold shore water ceased abruptly at Cape Blanco, lat. 4° 27′ S., and during the passage round this cape from Payta to the entrance of the Guayaquil River, lat. 3° 9′ S., the temperature of the water rose from 17·1° to 25·2° C. From this locality a pretty straight line was followed across the equatorial current near its source to Panama, lat. 9° 0′ N. During the passage the temperature of the water varied between 25° and 27° C., and it maintained a blue colour throughout. At Panama, however, with a temperature of 27° C., the water was quite green.

A similar occurrence of cold and green water near the shore was observed on the North American coast from Cape San Lucas, at the extremity of the Californian peninsula, to San Francisco. In the equatorial waters which wash the coast from Cape Blanco, lat. 4° 27′ S., to Panama, and thence to Cape Corrientes, lat. 20° 25′ N., long. 105° 43′ W., green water is prevalent along the shore, but its temperature is very high, 28° or 29° C. Further information on this subject will be found in a paper by me on similarities in the physical geography of the great oceans (Proceedings of the Royal Geographical Society, 1886, viii., p. 753).

I will here refer to only one other locality, and that a well-known one, where the weather shore of an ocean is associated with green water of abnormally low temperature, namely, the east coast of North America from Florida to Nova Scotia. The cold and green water which is found on this coast, and lying between it and the western edge of the Gulf Stream, is usually attributed to the Labrador current, which is charged with the duty of bringing cold water from Baffin's Bay as a surface current round Newfoundland and down the coast to Cape Hatteras and even beyond it. The principle was the same as that which moved Humboldt to attribute the cold water, which we have described in connection with the Pacific coast of tropical South America, to a surface current from the Antarctic Ocean. In the paper on similarities, &c., above referred to, I showed that Humboldt's explanation postulated an impossibility. The deeper layers of the water on the coast itself are capable of supplying, as and when required, much more cold than is wanted, and that with the least expenditure of energy. The same is the case with the "cold wall." Besides the south-westerly winds of the North Atlantic, and perhaps independently of them, the Gulf Stream itself, pouring its waters in a stream of great momentum past the American coast and out into the open ocean, performs the function of a colossal jet-pump, carrying water away from the surface and leaving its place to be taken by the other water which can get there most easily. This is the cold water of the deeper layers *in situ*. It is this hydraulic cold-water service which tempers the climate of the eastern States. The labours of the U.S. Coast Survey during the last seventy years have shown that fluctuations, both regular and irregular, occur in the flow of the Gulf Stream. These necessarily react on the supply of cold water drawn from the deep and spread over the continental shelf. Such variations are probably the source of the accidents which occasionally occur and cause the extinction of life over large tracts of shoal water on that coast.

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REMNANTS OF THE PAST.

MUCH interest attaches to a paper by Mr. R. S. Lull, published in the "Proceedings of the Seventh International Zoological Congress, Boston, 1907" (issued 1910), on the evolution of the horned dinosaurs, or Ceratopsia. Although early ancestral forms are at present unknown, it is probable that the group took origin from an iguanodont stock. The earliest known types are Monoclonius and Ceratops of the Judith River beds, the single representative of the former being the more primitive, and probably ancestral to all the rest. In Monoclonius the orbital horns are much smaller than the nasal one, but in one species of Ceratops the two have become subequal; both genera show large vacuities in the cervical flange of the skull, which was probably internal. Between the Judith River and Laramie formations occur certain marine formations yielding no dinosaurian remains, but in the basal Laramie occur Agathaumas, of which the skull is unknown. Higher up this is succeeded by Triceratops, in which the vacuities in the cervical flange are obliterated, while in the various species may be traced a gradual increase in the size of the orbital at the expense of the nasal horn, the latter becoming almost obsolete in *T. elatus*, while it has disappeared in Diceratops, which forms a side-branch by itself. The remarkable genus Torosaurus of the Upper Laramie, although having developed large orbital horns at the expense of the nasal one, retains the long, straight skull, with a large vacuity in the cervical flange, of the Judith River *Ceratops monatus*, from which it may be directly descended. Physical changes in their environment seem, in the author's opinion, the most probable cause of the extinction of these marvellous reptiles.

In the April number of the *American Journal of Science* Mr. F. Loomis describes the complete skeleton of a new species of the camel-like genus Stenomylus from the Harrison beds of Nebraska. The genus differs from other Tertiary types by the hypsodont character of the dentition. This is considered by Mr. Loomis as an indication that Stenomylus differed from its relatives in habits. The early tylopods of the Protomeryx type probably fed on a mixed diet, while the members of the long-limbed Oxydactylus group may have subsisted on leaves and shoots, both retaining the original brachyodont dentition. Stenomylus, on the other hand, seems to represent a separate branch derived from the ancestral Poëbrotherium, which developed a hypsodont dentition, and took to feeding on hard-stemmed grasses growing on open, arid plains.

Dr. A. E. Ortmann contributes to the April number of the *American Naturalist* an article on the theory that a connection between Africa and South America persisted into the Tertiary. According to the Archelenis theory, as originally proposed by Dr. von Ihering, an ancient connection between the above-named continents was the last remnant of the much greater equatorial land-mass known as Gondwanaland, an area which was broken up at various dates, and remnants of which are represented by Australia, India, Africa, and Brazil. The separation of Brazil from Africa was the final stage in the dismemberment of the old continent, and it is generally considered that this took place towards the close of the Mesozoic epoch. A study of the Tertiary flora of Patagonia has, however, induced Dr. von Ihering to believe that Archelenis persisted into the Tertiary. It is argued, however, that the facts cited by von Ihering really lead to just the opposite conclusion, while the existence of marine Eocene deposits in many parts of West Africa is likewise an indication that the connection between the two continents had ceased. Accordingly, the evidence for a Tertiary Archelenis is considered valueless.

Vol. vii., No. 2, of the University of Colorado Studies is devoted to an account, by several authors, of the results of a scientific expedition to north-western Colorado. In a paper on plant-remains from the Cretaceous of Mesa Verde, Prof. T. D. A. Cockerell describes and figures a fragment of a branch bearing a remarkable resemblance to the Palæozoic lycopods of the Ulodendron type. It really belongs to an araucarian conifer (*Geinitzia reichenbachi*), but its resemblance to lycopods of an earlier period is highly significant in view of the probability of a real relationship between the two groups.

NON-FERROUS METALS.

IN many respects the second volume of the journal of the Institute of Metals marks a decided advance on the first volume—an advance which serves as a healthy sign of the continued growth of the institute. Perhaps the best sign of this advance is the inclusion, in the second volume, of a series of abstracts of scientific and technical literature bearing upon the subjects which come within the scope of the institute. These abstracts fill what has hitherto been a decided gap in metallurgical literature; they are obviously modelled on the very excellent abstracts of the literature of iron and steel which appeared in the Journal of the Iron and Steel Institute while that journal was under the editorship of the late Mr. Bennett Brough. Perhaps the most serious criticism to be offered on these abstracts is that they are of too indiscriminate a character, mere descriptive papers of small permanent interest being accorded equal space with papers of real importance.

The original papers, which, with the discussions, occupy the greater part of the second volume, have already been referred to in these pages on the occasion of the meeting at which they were read. It is satisfactory to find that the discussions show signs of free and vigorous criticism, and that such criticism seems to be accepted by the authors in a kindly spirit, even though at times the criticisms are practically destructive. Thus the first paper (Edwards and Andrew on aluminium-copper-tin alloys) is criticised on the ground that the data published do not afford sufficient insight into the facts upon which the authors base their conclusions. The paper of Prof. Turner and Mr. Murray, on the volume-changes of the copper-zinc alloys, is also challenged as regards the validity of its conclusions on the ground—apparently justified—that the mere measurement of the longitudinal contraction of a casting can give no true insight into the volume-changes which accompany the passage of the metal from the liquid to the solid state. More than eighty pages of the volume are devoted to the paper of Mr. A. C. M. Smith on the elastic breakdown of non-ferrous metals, and although the subject presents certain points of interest, it appears to occupy a good deal more than its fair share of space in a journal not specially devoted to such questions as the best means of measuring elastic constants. The paper, however, shows clearly the narrow limits within which Hooke's law is applicable to such metals as copper and aluminium; the latter appears to be particularly unsatis-

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[1] The Journal of the Institute of Metals, vol. ii. Pp. 341. Vol. iii. Pp. xi + 360. Edited by G. Shaw-Scott, Secretary.